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John Hart
Sherman College of Chiropractic, Spartanburg, SC

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CANCER MORTALITY FOR A SINGLE RACE IN LOW VERSUS HIGH ELEVATION COUNTIES IN THE U.S.

John Hart, DC, MHSc □ Sherman College of Chiropractic

□ A previous study compared cancer mortality in the six lowest versus six highest elevations in the U.S. for all races. This study looks at a single race since death rates tend to vary by race. In this ecological study, cancer mortality rates were compared between low and high states for a race that had sufficient number of counties reporting mortality data, that is, the white race. The average cancer mortality rate for low elevation counties was 73.47 + 18.35 compared to 53.90 + 13.76 for high elevation counties, a difference that was statistically significant ($p < 0.0001$), with a very large effect size (of 1.2). Higher elevation counties showed less cancer mortality rates for a single race compared to lower elevation counties, suggesting the presence of radiation hormesis. Further rigorous research is indicated to verify or refute these findings.

Keywords: Background radiation, cancer death rates, altitude, medical geography, Caucasian race

INTRODUCTION

It is well known that levels of natural background radiation (NBR) increase with increasing land elevations (US NRC, 2009a). A previous study on this topic assessed cancer mortality in regard to *all* races for the six lowest versus six highest land elevations at the state level and found less cancer mortality in higher elevations (Hart, 2010). Because cancer mortality rates tend to be different between races (Albano et al, 2007), it seems helpful to study a single race when looking for differences in possible effects from a variable such as NBR. As an example of cancer mortality differences between races, Black and Hispanic women have been found to experience higher age-adjusted cervical cancer mortality (Selvin and Brett, 2003). Thus, if there is a greater percentage of Black and Hispanic women in, say, low elevation locales, then analysis of low versus high elevation could show a higher cancer mortality rate in low elevation locations, suggesting, perhaps erroneously, that radiation hormesis is involved if racial differences are not taken into account. Consequently, it behooves the researcher to analyze a single race in to further investigate the possible presence of radiation hormesis in low versus high land elevations. To this end, the present study is different from the previous similar study (Hart, 2010) on two important points: 1) the present study

Address correspondence to John Hart, DC, MHSc, Assistant Director of Research, Sherman College of Chiropractic, P.O. Box 1452, Spartanburg, SC 29304; Phone: 864-578-8770, ext. 232; E-mail: jhart@sherman.edu

looks at data at the *county level* (instead of at the state level), thereby providing for a much larger sample size and 2) the present study looks at a *single* race rather than all races.

METHODS

The response variable in this study consisted of archived data from the National Cancer Institute (NCI) databases for age-adjusted cancer mortality rates, all sites cancer, age < 65, both genders, 2002-2006 by county (NCI, 2010) for the six lowest and six highest elevation jurisdictions in the U.S., including the District of Columbia (referred to now as "states). States were selected based on their mean elevations (USGS, 2005) and as previously detailed (Hart, 2010). Low elevation states consisted of Delaware, District of Columbia, Florida, Louisiana, Mississippi, and Rhode Island while high elevation states consisted of Colorado, Montana, New Mexico, South Dakota, Utah, and Wyoming. The elevation range for the low elevation states was 345 feet above sea level (Rhode Island) to 812 feet above sea level (Florida). The elevation range for the high elevation states was 966 feet above sea level (South Dakota) to 3315 feet above sea level (Colorado). Consequently, there was no overlap of land elevation between the two elevation categories. There were 210 counties having reportable data in the low elevation states and 171 counties in the high elevation states. The estimated levels of NBR by elevation were estimated to range from 51 to 74 mrem (mean = 62.5 + 12.6 standard deviations) for the low elevation states compared to 74 to 81 mrem (mean = 78.5 + 2.9 standard deviations) for high elevation states (NRC, 2009b).

If there were too few deaths for reliable statistical reporting for a given county, then NCI did not report any data for that county. The race category "Black including Hispanic" is provided by NCI but there were only six counties reporting data for the six states in the high elevation state category. Since selection of the race for this study was based on obtaining a large sample size, the Caucasian (white) race was selected in order to achieve a satisfactory sample size for this study that seeks to look at a single race. The age < 65 was used to assess mortality rates below the age of life expectancy.

Counties in the six lowest states versus six highest states were compared. Data analysis consisted determining whether the mortality rate was different between low and high elevation categories using: a) a test showing statistical differences using a two tailed alpha of 0.05 and b) effect size (Morgan et al, 2007). Since the cancer mortality data exhibited a non-normal distribution (skew = 2.37), the nonparametric Wilcoxon test was used to determine statistical differences; this was performed in SAS 9.2 (Cary, NC). Effect size was calculated in a spreadsheet with a formula outlined by Morgan et al (2007), using a pooled standard deviation.

Interpretation of effect size values were as follows: Very large = greater than or equal to 1.00; Large = 0.80; Medium = 0.50; Small = 0.20 (Morgan et al, 2007). Statistical power for comparing the mean cancer mortality between low and high elevation states was performed with an online power calculator (Researcher's toolkit, 1995-2009).

RESULTS

Summary data by county is provided in Table 1. The average cancer mortality rate for low elevation counties was 73.47 + 18.35 compared to 53.90 + 13.76 for high elevation counties. This difference was statistically significant ($p < 0.0001$) with a statistical power of 100% and a very large effect size (of 1.2) (Figure 1).

TABLE 1. Cancer mortality rates ("rate") by county (NCI, 2010). Elevations from U.S. Geological Survey (USGS, 2005).

Low elevation states (345 feet above sea level to 812 feet above sea level)					
State	County	Rate	State	County	Rate
DE	Kent County	67.8	LA	Ouachita Parish	63.2
DE	New Castle County	56.5	LA	Plaquemines Parish	63.1
DE	Sussex County	74.4	LA	Pointe Coupee Parish	66.9
DC	District of Columbia	40.8	LA	Rapides Parish	66.6
FL	Alachua County	57.9	LA	Red River Parish	90.3
FL	Baker County	83.2	LA	Richland Parish	93.3
FL	Bay County	67.6	LA	Sabine Parish	83.0
FL	Bradford County	71.1	LA	St. Bernard Parish	88.5
FL	Brevard County	70.3	LA	St. Charles Parish	56.7
FL	Broward County	64.7	LA	St. Helena Parish	73.8
FL	Calhoun County	75.6	LA	St. James Parish	52.0
FL	Charlotte County	67.6	LA	St. John the Baptist Parish	56.5
FL	Citrus County	81.2	LA	St. Landry Parish	75.3
FL	Clay County	70.1	LA	St. Martin Parish	72.9
FL	Collier County	52.3	LA	St. Mary Parish	80.6
FL	Columbia County	75.4	LA	St. Tammany Parish	61.0
FL	DeSoto County	73.0	LA	Tangipahoa Parish	80.1
FL	Dixie County	108.0	LA	Tensas Parish	102.2
FL	Duval County	67.3	LA	Terrebonne Parish	72.4
FL	Escambia County	71.7	LA	Union Parish	63.6
FL	Flagler County	74.5	LA	Vermilion Parish	91.4
FL	Franklin County	77.9	LA	Vernon Parish	75.8
FL	Gadsden County	66.2	LA	Washington Parish	97.3
FL	Gilchrist County	69.1	LA	Webster Parish	105.9
FL	Glades County	58.4	LA	West Baton Rouge Parish	57.1
FL	Gulf County	73.8	LA	West Carroll Parish	78.6
FL	Hamilton County	70.1	LA	West Feliciana Parish	59.9
FL	Hardee County	71.5	LA	Winn Parish	90.2
FL	Hendry County	80.6	MS	Adams County	76.1
FL	Hernando County	84.4	MS	Alcorn County	67.7
FL	Highlands County	71.8	MS	Amite County	70.4
FL	Hillsborough County	64.7	MS	Attala County	54.5

Continued

TABLE 1. *Continued*

Low elevation states (345 feet above sea level to 812 feet above sea level)					
State	County	Rate	State	County	Rate
FL	Holmes County	90.3	MS	Benton County	75.7
FL	Indian River County	69.8	MS	Bolivar County	71.0
FL	Jackson County	69.0	MS	Calhoun County	62.7
FL	Jefferson County	78.3	MS	Carroll County	50.6
FL	Lafayette County	87.9	MS	Chickasaw County	59.5
FL	Lake County	76.0	MS	Choctaw County	55.4
FL	Lee County	63.8	MS	Clarke County	69.5
FL	Leon County	56.3	MS	Clay County	82.4
FL	Levy County	88.7	MS	Coahoma County	84.0
FL	Liberty County	87.4	MS	Copiah County	76.3
FL	Madison County	90.4	MS	Covington County	70.3
FL	Manatee County	70.4	MS	DeSoto County	67.0
FL	Marion County	85.5	MS	Forrest County	66.1
FL	Martin County	65.0	MS	George County	86.7
FL	Miami-Dade County	58.5	MS	Greene County	97.8
FL	Monroe County	68.7	MS	Grenada County	80.2
FL	Nassau County	79.8	MS	Hancock County	77.5
FL	Okaloosa County	58.0	MS	Harrison County	82.4
FL	Okeechobee County	104.1	MS	Hinds County	50.3
FL	Orange County	60.8	MS	Holmes County	123.2
FL	Osceola County	71.3	MS	Itawamba County	84.3
FL	Palm Beach County	58.0	MS	Jackson County	69.0
FL	Pasco County	81.9	MS	Jasper County	67.4
FL	Pinellas County	68.1	MS	Jefferson Davis County	87.2
FL	Polk County	81.9	MS	Jones County	72.7
FL	Putnam County	98.3	MS	Lafayette County	55.7
FL	Santa Rosa County	57.3	MS	Lamar County	71.1
FL	Sarasota County	62.4	MS	Lauderdale County	72.7
FL	Seminole County	51.7	MS	Lawrence County	69.8
FL	St. Johns County	60.0	MS	Leake County	72.0
FL	St. Lucie County	74.3	MS	Lee County	74.8
FL	Sumter County	68.2	MS	Leflore County	55.9
FL	Suwannee County	87.1	MS	Lincoln County	65.6
FL	Taylor County	83.6	MS	Lowndes County	56.7
FL	Union County	244.2	MS	Madison County	112.7
FL	Volusia County	77.5	MS	Marion County	102.1
FL	Wakulla County	80.8	MS	Marshall County	91.0
FL	Walton County	69.9	MS	Monroe County	65.6
FL	Washington County	98.7	MS	Montgomery County	55.6
LA	Acadia Parish	78.5	MS	Neshoba County	62.8
LA	Allen Parish	64.5	MS	Newton County	49.2
LA	Ascension Parish	58.8	MS	Oktibbeha County	52.1
LA	Assumption Parish	72.0	MS	Panola County	86.8
LA	Avoyelles Parish	88.1	MS	Pearl River County	83.2
LA	Beauregard Parish	85.3	MS	Perry County	115.1
LA	Bienville Parish	72.3	MS	Pike County	89.5
LA	Bossier Parish	69.5	MS	Pontotoc County	69.7
LA	Caddo Parish	68.2	MS	Prentiss County	76.7
LA	Calcasieu Parish	74.1	MS	Rankin County	57.3
LA	Caldwell Parish	71.8	MS	Scott County	71.3

Continued

TABLE 1. *Continued*

Low elevation states (345 feet above sea level to 812 feet above sea level)					
State	County	Rate	State	County	Rate
LA	Cameron Parish	93.8	MS	Simpson County	79.4
LA	Catahoula Parish	67.5	MS	Smith County	92.3
LA	Claiborne Parish	49.6	MS	Stone County	63.2
LA	Concordia Parish	82.8	MS	Sunflower County	87.6
LA	De Soto Parish	69.5	MS	Tallahatchie County	48.3
LA	East Baton Rouge Parish	53.4	MS	Tate County	77.2
LA	East Feliciana Parish	51.8	MS	Tippah County	65.7
LA	Evangeline Parish	71.0	MS	Tishomingo County	69.4
LA	Franklin Parish	60.0	MS	Union County	61.8
LA	Grant Parish	53.6	MS	Walthall County	82.9
LA	Iberia Parish	73.0	MS	Warren County	71.1
LA	Iberville Parish	75.2	MS	Washington County	65.9
LA	Jackson Parish	49.2	MS	Wayne County	81.8
LA	Jefferson Davis Parish	67.7	MS	Webster County	77.1
LA	Jefferson Parish	64.6	MS	Wilkinson County	101.4
LA	La Salle Parish	84.3	MS	Winston County	54.7
LA	LaFourche Parish	65.7	MS	Yalobusha County	106.3
LA	Lafayette Parish	67.2	MS	Yazoo County	85.0
LA	Lincoln Parish	59.3	RI	Bristol County	53.7
LA	Livingston Parish	74.8	RI	Kent County	63.9
LA	Morehouse Parish	73.3	RI	Newport County	57.8
LA	Natchitoches Parish	62.8	RI	Providence County	64.7
LA	Orleans Parish	61.8	RI	Washington County	48.4
High elevation states (966 feet above sea level to 3315 feet above sea level)					
State	County	Rate	State	County	Rate
CO	Adams County(7)	59.6	NM	Los Alamos County	19.5
CO	Alamosa County	51.9	NM	Luna County	72.7
CO	Arapahoe County	41.3	NM	McKinley County	55.3
CO	Archuleta County	36.4	NM	Otero County	66.1
CO	Baca County	98.8	NM	Quay County	80.9
CO	Bent County	82.9	NM	Rio Arriba County	55.7
CO	Boulder County(7)	38.2	NM	Roosevelt County	64.0
CO	Broomfield County(7)	43.1	NM	San Juan County	55.5
CO	Chaffee County	33.8	NM	San Miguel County	65.5
CO	Clear Creek County	34.8	NM	Sandoval County	54.5
CO	Delta County	47.9	NM	Santa Fe County	43.4
CO	Denver County	52.9	NM	Sierra County	98.9
CO	Douglas County	32.6	NM	Socorro County	78.0
CO	Eagle County	35.3	NM	Taos County	41.4
CO	El Paso County	51.9	NM	Torrance County	44.5
CO	Elbert County	31.7	NM	Valencia County	62.5
CO	Fremont County	61.6	SD	Beadle County	57.3
CO	Garfield County	38.3	SD	Bon Homme County	60.7
CO	Grand County	36.0	SD	Brookings County	58.0
CO	Gunnison County	49.6	SD	Brown County	50.5
CO	Jefferson County(7)	44.8	SD	Brule County	81.0
CO	Kit Carson County	52.4	SD	Butte County	55.2
CO	La Plata County	40.2	SD	Charles Mix County	49.9

Continued

TABLE 1. *Continued*

High elevation states (966 feet above sea level to 3315 feet above sea level)					
State	County	Rate	State	County	Rate
CO	Larimer County	41.7	SD	Clay County	57.1
CO	Las Animas County	46.1	SD	Codington County	63.5
CO	Logan County	56.4	SD	Custer County	46.9
CO	Mesa County	56.8	SD	Davison County	47.5
CO	Moffat County	52.5	SD	Fall River County	53.4
CO	Montezuma County	72.7	SD	Grant County	51.7
CO	Montrose County	50.7	SD	Gregory County	81.9
CO	Morgan County	51.7	SD	Hamlin County	81.9
CO	Otero County	63.8	SD	Hughes County	44.2
CO	Park County	32.2	SD	Lake County	43.8
CO	Pitkin County	33.0	SD	Lawrence County	49.7
CO	Prowers County	91.9	SD	Lincoln County	64.3
CO	Pueblo County	59.6	SD	Meade County	68.2
CO	Rio Grande County	56.8	SD	Minnehaha County	59.0
CO	Routt County	41.9	SD	Pennington County	51.4
CO	Saguache County	62.2	SD	Roberts County	46.4
CO	Summit County	28.7	SD	Tripp County	72.7
CO	Teller County	52.0	SD	Turner County	40.2
CO	Weld County(7)	55.6	SD	Union County	51.6
CO	Yuma County	69.3	SD	Yankton County	57.4
MT	Beaverhead County	35.9	UT	Beaver County	77.3
MT	Broadwater County	84.3	UT	Box Elder County	42.7
MT	Carbon County	50.7	UT	Cache County	31.9
MT	Cascade County	52.8	UT	Carbon County	42.5
MT	Custer County	75.4	UT	Davis County	41.3
MT	Dawson County	53.6	UT	Duchesne County	58.0
MT	Deer Lodge County	61.2	UT	Emery County	58.9
MT	Fergus County	65.0	UT	Grand County	45.3
MT	Flathead County	52.3	UT	Iron County	53.2
MT	Gallatin County	36.6	UT	Millard County	36.2
MT	Hill County	47.0	UT	Salt Lake County	45.5
MT	Jefferson County	44.8	UT	San Juan County	72.8
MT	Lake County	41.5	UT	Sanpete County	48.8
MT	Lewis and Clark County	50.1	UT	Sevier County	41.4
MT	Lincoln County	50.8	UT	Summit County	35.4
MT	Madison County	35.0	UT	Tooele County	48.7
MT	Mineral County	66.4	UT	Uintah County	51.8
MT	Missoula County	43.1	UT	Utah County	38.2
MT	Musselshell County	67.3	UT	Wasatch County	43.3
MT	Park County	57.6	UT	Washington County	59.4
MT	Pondera County	69.5	UT	Weber County	47.7
MT	Powell County	77.7	WY	Albany County	37.2
MT	Ravalli County	61.3	WY	Big Horn County	49.1
MT	Richland County	67.8	WY	Campbell County	48.4
MT	Rosebud County	68.2	WY	Carbon County	50.6
MT	Sanders County	74.9	WY	Converse County	45.3
MT	Sheridan County	72.5	WY	Crook County	51.9
MT	Silver Bow County	48.3	WY	Fremont County	53.7
MT	Stillwater County	37.6	WY	Goshen County	32.4
MT	Teton County	55.8	WY	Hot Springs County	58.9

Continued

TABLE 1. *Continued*

High elevation states (966 feet above sea level to 3315 feet above sea level)					
State	County	Rate	State	County	Rate
MT	Valley County	52.0	WY	Johnson County	50.2
MT	Yellowstone County	55.0	WY	Laramie County	61.1
NM	Bernalillo County	50.9	WY	Lincoln County	37.6
NM	Chaves County	74.6	WY	Natrona County	58.3
NM	Cibola County	64.5	WY	Park County	51.6
NM	Colfax County	41.9	WY	Platte County	67.5
NM	Curry County	57.5	WY	Sheridan County	60.2
NM	Dona Ana County	57.4	WY	Sublette County	46.0
NM	Eddy County	67.3	WY	Sweetwater County	54.0
NM	Grant County	61.9	WY	Teton County	41.0
NM	Lea County	60.1	WY	Uinta County	51.0
NM	Lincoln County	55.6	WY	Washakie County	48.5
			WY	Weston County	64.2

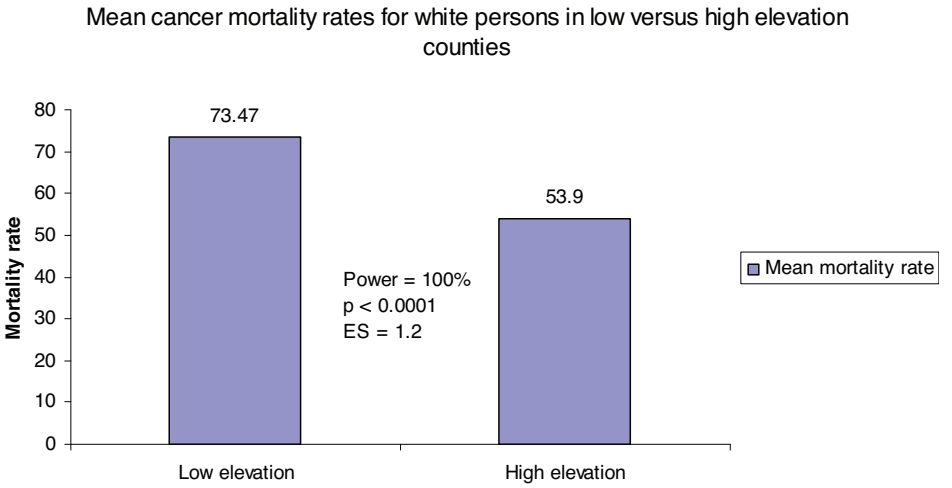

FIGURE 1. Mean cancer mortality rates for white persons in low versus high elevation counties.

CONCLUSION

This study showed a statistically significant lower cancer mortality rate in high elevation counties compared to lower elevation counties. This suggests the presence of radiation hormesis. However, since this is an ecological study, causal inferences are less apparent than, say, case-control studies. Future, more rigorous studies will help to either verify or refute these findings.

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